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Conodont Biostatigraphy and Paleoecology of the Upper Ordovician Miamitown Shale in the Cincinnati Region, Ohio

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Conodont Biostratigraphy and Paleoecology of the Upper Ordovician Miamitown Shale in the Cincinnati Region, Ohio

Presented in Partial Fulfillment
of the Requirements for the Bachelor of Science Degree

By
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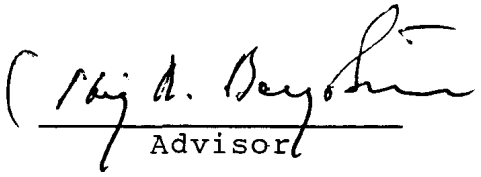
1989



Advisor

Table of Contents

Abstract.....2

Introduction.....2

Miamitown Shale.....3

Location.....4

Methods of Study.....14

Conodont Paleoecology.....19

Biostratigraphy.....32

Conclusion.....37

Acknowledgments.....38

Abstract

In order to study the conodont paleoecology, biostratigraphy, and depositional environment of the Miamitown Shale, 11 samples were collected from three localities near Miamitown. All samples were productive and yielded well preserved conodonts. The relative frequency of Amorphognathus, Icriodella, Phragmodus, and Plectodina indicate a progressive deepening of the depositional environment from the uppermost Fairview Formation into the Miamitown Shale, and a shallowing at the top of the Miamitown and into the overlying Bellevue Formation. The presence of elements of A. superbus in the lower Miamitown shows that the top of the A. superbus zone is stratigraphically higher than has been assumed previously in the literature. Apparently this key stratigraphic level is in the upper Miamitown or higher, which necessitates a revision of the regional correlation of this portion of the Cincinnatian Series, the reference sequence of the North American Upper Ordovician.

Introduction

The purpose of this study was to investigate the paleoecology and biostratigraphy of the Miamitown Shale by using conodonts.

The paleoecology of the Miamitown Shale provides important data for determining the depositional environment and paleogeography of the Cincinnati region during part of the Late

Ordovician. The conodont fauna of the Miamitown Shale is abundant but has not been studied in detail previously. Several models of the paleoecology of the Cincinnati region have been developed. By utilizing the relative abundance and percentage of several species of conodonts within two measured sections, this study will develop a possible paleoecologic scenario through the use of an established paleoecological model of conodont depth stratification.

The reference standard of the North American Upper Ordovician, the Cincinnatian Series, is in the Cincinnati region, and the Miamitown Shale is a part of this key succession. However, the precise biostratigraphic position of this unit in terms of global conodont zones has been uncertain. More specifically, it has been unknown if the important Amorphognathus superbus - Amorphognathus ordovicicus zonal boundary is below, within, of above the Miamitown Shale. Hence a second objective of this study was to determine the biostratigraphic position of the Miamitown Shale in terms of conodont zones.

Miamitown Shale

The Miamitown Shale is named for Miamitown, Ohio, where the type section is a now largely covered road cut along I-74, one mile west of Miamitown.

The Miamitown Shale consists primarily of shale and mudstone but it has a few widely spaced limestone layers. The thickness

of the unit is 5 feet at Clifton Hill, Cincinnati, and it thickens northwestward to 17 feet at Miamitown, and to 35 feet 4 miles northwest of Miamitown (Ford, 1967). The Miamitown Shale forms a tongue with an east-southeastward to west-northwestward strike and exhibits a northwest-thickening trend (Ford, 1967). According to Ford (1967), the Miamitown Shale represents a return to conditions prevailing during the deposition of the lowermost Cincinnatian Kope Formation.

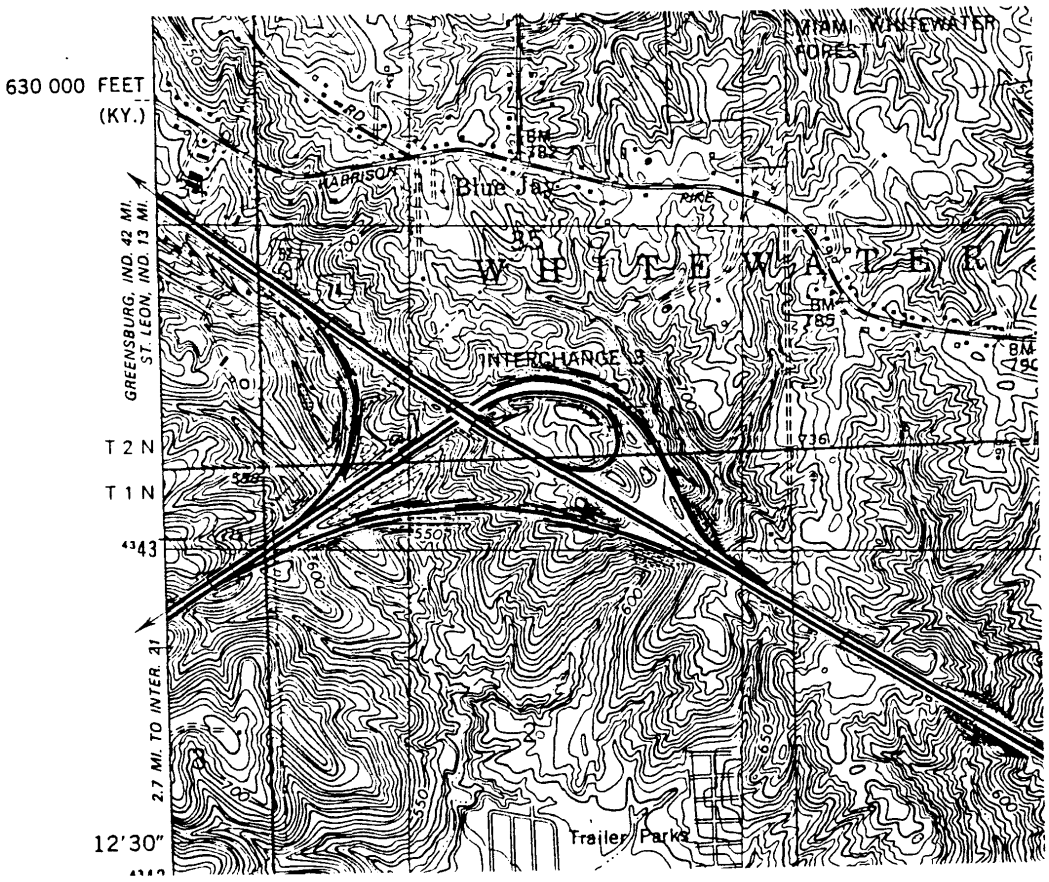
The Miamitown Shale is structurally simple with no apparent dip. If any structures are present they are the result of local depositional features. The unit is overlain by the Bellevue Formation and underlain by the Fairview Formation. The Miamitown Shale eventually pinches out to the southeast between the Bellevue Formation and Fairview Formation across the Ohio River in Kentucky. According to Hay, Pope, and Frey (1981), the Fairview Formation pinches out to the west near Wayne County, Indiana where the Miamitown Shale and Kope Formation merge.

The Miamitown Shale is dark gray to dark blue-gray, and weathers gray to a light blue-gray. The shale and mudstone portion of the Miamitown Shale, along with the widely spaced limestone layers, contain a large amount of terrigenous detritus (Ford, 1967). The Miamitown Shale has a characteristic macrofaunal assemblage including Lophospira, Cyclonema, and Byssonychia (Ford, 1967).

Location

In order to examine the paleoecology and biostratigraphy of the Miamitown Shale, two localities were selected with exposures

Figure 1 Location (stars) of each section, Miamitown West and Miamitown East.



From Addyston Quadrangle
Contour Interval 10 feet
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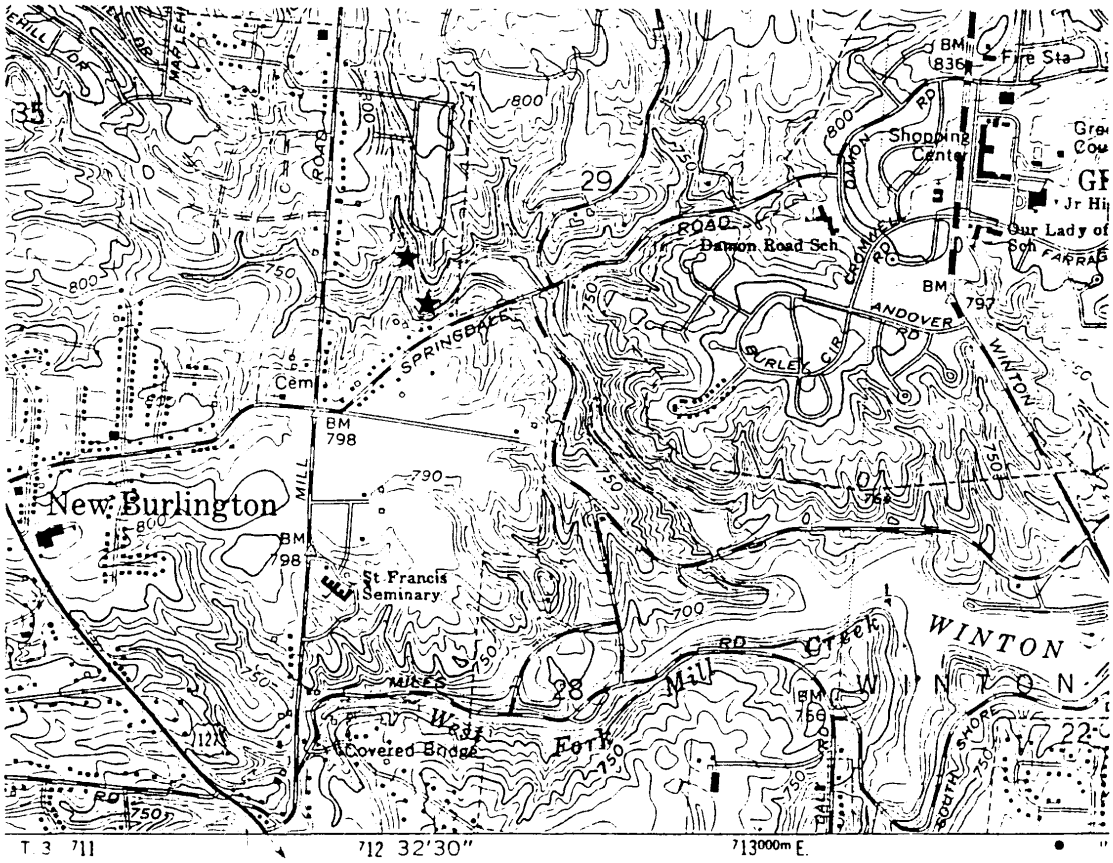
Figure 2 Star indicates the location of the Miamitown West Section.



From Greenhills Quadrangle

Contour Interval 10 feet

Scale 1:24 000

Figure 3 Stars indicate location of Miamitown East Section, I and II.

Figure 4

Outcrop of the Miamitown Shale, at the Miamitown West Section. Interval with arrow indicates the Miamitown Shale.

Close-up of the Miamitown West Section, showing the Miamitown Shale/Bellevue Formation contact.

Figure 5

Miamitown East Section I, Miamitown Shale/Bellevue Formation contact. (Student for scale)

Miamitown East Section II, Miamitown Shale/Fairview Formation contact at the base of the slope.

Figure 6 Miamitown West Section

(Showing locations of sample horizons)

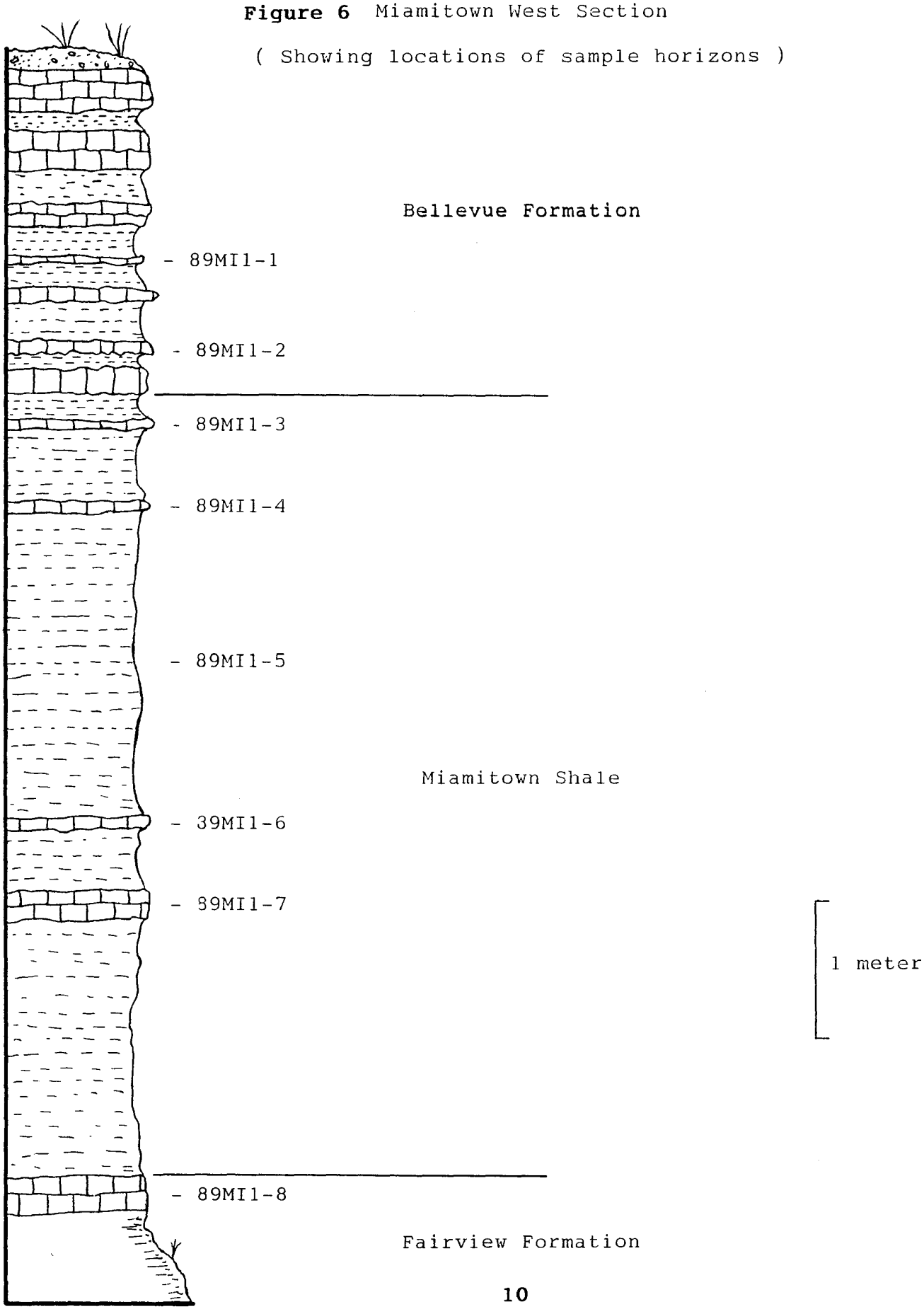


Figure 7 Miamitown East Section

(Showing locations of sample horizons)

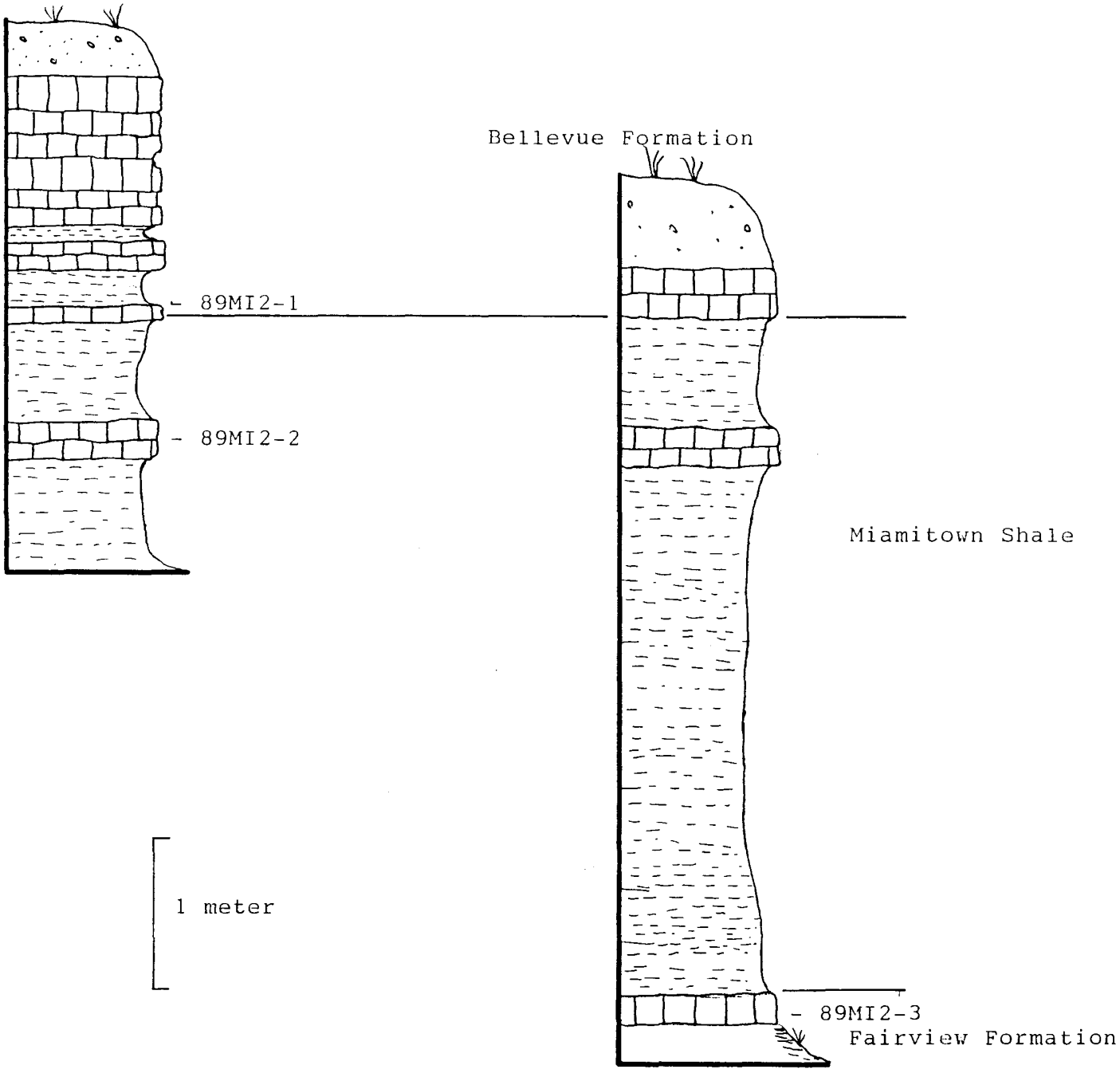
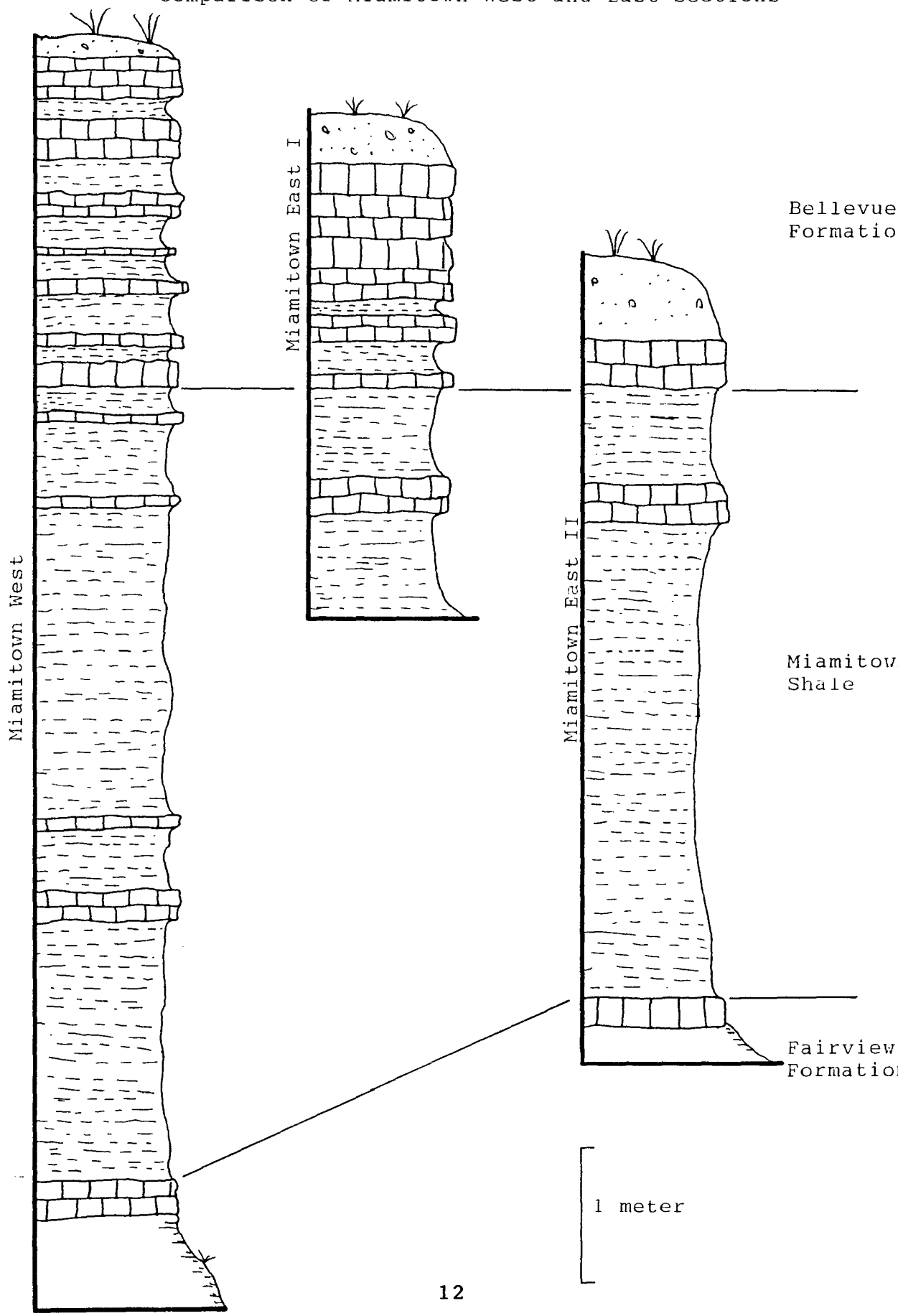


Figure 8

Comparison of Miamitown West and East Sections



of the entire Miamitown Shale. I refer to the first section as Miamitown West (Samples 89MI1-1 through 89MI1-8) and the second section as Miamitown East (Samples 89MI2-1 through 89MI2-3). For a map of the entire field area see Figure 1.

The first locality, Miamitown West, is at the intersection of I-74 and I-275 west of Miamitown (see Figure 2 and 4). The section is located on the exit ramp of I-275, north bound, to east bound I-74 and is on the north side of the road cut. The Miamitown West section is in Whitewater Township in Hamilton County and can be found on the Addyston Quadrangle map. The base of the section is approximately 800 feet above sea level and the unit is approximately 19 feet thick (see Figure 6).

The second section, Miamitown East, is located near the northeast corner of the intersection of Springdale road and Mill road (see Figure 3 and 5). At this locality outcrops of the Miamitown Shale occur along a small unnamed creek north of Springdale road. This stream flows into the western edge of the nearby Winton Lake (see Figure 3). Two sections were used at this locality to obtain samples. Miamitown East section I is a southward facing exposure along the creek and Miamitown East section II is located on an exposure that faces northeastward along the creek. Miamitown East section I is approximately 720 feet above sea level and only 6 feet of the Miamitown Shale is exposed here (see Figures 3,5 and 6). Miamitown East section II is approximately 710 feet above sea level and a complete 14 foot section is exposed here (see Figures 3,5 and 6). The Miamitown

East section is located in Springfield Township in Hamilton County and can be found on the Greenhills Quadrangle map.

A total of 11 samples were collected, 8 samples from the Miamitown West section and 3 samples from the Miamitown East section. An additional sample was contributed by Dr. S.M. Bergstrom (sample 88B60-1). For a complete listing of sampled levels see Tables 1-3 and Figures 6-7.

Methods of Study

The collected samples were brought back to the laboratory for analysis. Approximately 3 kilograms of sample were collected from each horizon but only 2 kilograms were processed (see Table 2). The first step was to crush each sample to approximately 1/4 inch sized fragments. In order to isolate the conodonts from the rock, 2 kilograms of sample were first weighed and then placed into buckets containing approximately 700 ml of glacial acetic acid to 6 quarts of water. This step was repeated twice with a final acid bath of 300 ml of glacial acetic acid to 6 quarts of water to finish the sample digestion. The remaining undigested sediment was washed through 20 and 140 mesh sieves to get rid of excess clay particles.

The 11 samples included contained 10 limestone samples and one shale sample. The shale sample was first dried in an oven at 250 degrees Fahrenheit for one hour. The dry shale sample was then placed into a bucket and covered with enough kerosene to just cover the sample and then allowed to sit for 8 hours. The kerosene was then filtered off for reuse. Hot water was then added to disintegrate the shale. The shale sample was then

Table 1

(Samples with location and horizon)

Miamitown West:

89MI1-1	1 m Above the Miamitown Shale/Bellevue Formation contact.
89MI1-2	50 cm Above this contact.
89MI1-3	25 cm Below the Miamitown/Bellevue contact.
89MI1-4	90 cm Below this contact.
89MI1-5	Shale sample, 2 m below this contact.
89MI1-6	3.25 m Below this contact. *Amorphognathus superbus* found at this horizon.
89MI1-7	4 m Below this contact.
89MI1-8	6 m Below this contact, top part of the Fairview Formation.

Miamitown East:

89MI2-1	Basal part of the Bellevue Formation.
89MI2-2	1 m Below the Miamitown/Bellevue contact.
89MI2-3	4.5 m Below this contact, the top part of the Fairview Formation.

Table 2

Sample weights

Sample #	Sample raw weight (kg)	Amount processed (kg)	Amount remaining (kg)
89MI1-1	3.43	3.32	0.55
89MI1-2	3.88	2.70	0.12
89MI1-3	3.34	2.68	0.11
89MI1-4	3.94	2.66	0.11
89MI1-5	2.20	2.08	0.27
89MI1-6	4.04	2.68	0.24
89MI1-7	5.05	2.78	0.11
89MI1-8	2.45	2.36	0.12
89MI2-1	3.47	2.76	0.13
89MI2-2	3.31	2.71	0.10
89MI2-3	2.74	2.70	0.13

Table 3

Sample Lithology

(Classification after Dunham, R.J., 1962)

Miamitown West:

89MI1-1 Bellevue Formation: Compact wackestone with broken brachiopods (shells not parallel to bedding), about 2% sparite, Light blue-gray weathers to a yellow-tan. Possible high energy depositional environment.

89MI1-2 Bellevue Formation: Compact wackestone with broken brachiopods and gastropods, light blue-gray weathers to a yellow-tan. Possible high energy depositional environment.

89MI1-3 Miamitown Shale: Compact mudstone with broken brachiopods and bryozoans, blue-gray weathers to a yellow-tan. Possible moderate energy depositional environment.

89MI1-4 Miamitown Shale: Wackestone with broken brachiopods and bryozoans (not parallel to bedding), irregular bedding, light blue-gray weathers to a yellow-tan. Possible high energy depositional environment.

89MI1-5 Miamitown Shale: Mudstone with some bioturbation, nonfissile, dark gray weathers to a light gray. Possible low energy depositional environment.

Table 3
(continued)

Miamitown West:

89MI1-6 Miamitown Shale: Compact calcareous mudstone with a lack of large clasts and/or shell fragments, no apparent bedding, dark blue-gray weathers to a light yellow-tan. Possible low energy depositional environment.

89MI1-7 Miamitown Shale: Packstone with brachiopods, bryozoans and gastropods (all broken and parallel to bedding), irregular bedding, light gray-mauve weathers to a dark yellow-tan. Possible high energy depositional environment.

89MI1-8 Fairview Formation: Crystalline carbonate with 90% sparite, 10% broken shell fragments, bedding obscured, light gray weathers to a light yellow-tan. Possible moderate to high energy depositional environment.

Miamitown East:

89MI2-1 Bellevue Formation: Wackestone with unbroken brachiopods (parallel to bedding), blue gray weathers to a light blue-gray. Moderate to high energy depositional environment.

89MI2-2 Miamitown Shale: Wackestone with broken brachiopods (parallel to bedding), gray-blue weathers to a light blue-gray. Possible moderate to high energy depositional environment.

89MI2-3 Fairview Formation: Wackestone with brachiopods and bryozoans (parallel to bedding), dark blue-gray weathers to a light yellow-tan. Possible high energy depositional environment.

filtered through 20 and 140 mesh sieves to remove all excess clay particles.

The 11 sample residues were placed in the magnetic separator to get rid of a major portion of magnetic materials (see Table 2). The residues that were still too large for easy picking were reduced using density separation. Tetrabromoethane , or TBE, was used to float off all of the lighter fraction of the residues, such as quartz. After this final reduction the samples were ready to be picked using a binocular microscope. Each genus was arranged on a slide with all elements of a particular genus arranged next to one another. A total of 1,596 conodonts were retrieved from the 11 samples. Selected specimens of the species found are illustrated in Plate I.

Conodont Paleoecology

The Cincinnati region includes an area of Southwestern Ohio, Southeastern Indiana, and Northern Kentucky (see Figure 9). Several studies have been carried out on the Ordovician paleoecology of this region (Schumacher, 1987). In the case of conodonts, a study by Bergstrom and Sweet (1966), recognized that Phragmodus and Plectodina are the most characteristic midcontinent genera in the eastern part of the North American Midcontinent Province. Kohut and Sweet (1968) recognized these two dominant genera and gave the informal designation of "northern fauna" for this province and "southern province" for the area having the dominant genera Aphelognathus, Oulodus, and

Rhipidognathus. The "southern fauna" is associated with lithic features that indicate deposition in very shallow water. Barnes and Fahraeus (1975) noted that the "northern fauna" of the Midcontinent Province is associated with deeper water conditions with dominating Plectodina indicating a moderate water depth and dominating Phragmodus suggesting greater water depth. Sweet (1988) presented a model of conodont depth-stratification in a transect through the Cincinnati region showing seven different genera and their relative distribution (see Figure 10). Sweet (1979) mentions that the preference of a particular genus to a certain water depth region may be attributed to a nektobenthic or benthic lifestyle.

The genera found at both of my localities include Amorphognathus, Icriodella, Phragmodus, Plectodina, and Drepanoistodus (see Figure 11 and Plate I). For occurrence data see Tables 4 and 5. The specimens that are of paleoecologic importance include Amorphognathus, Icriodella, Phragmodus, and Plectodina. Drepanoistodus is a genus that occurs world-wide and is not very useful in determining paleoecologic conditions. Therefore, Drepanoistodus will not be used to determine the paleoecology in this report.

The Miamitown West section has all of the genera mentioned above. By plotting the abundance of conodont elements per kilogram of sample, plotting the percentage of each genus per sample, and then utilizing the transect model proposed by Sweet (1988), I attempted to get an idea of the changes in relative water depth through the study succession.

Figure 9 Models of conodont biofacies in the Ordovician of the Cincinnati region. (From Sweet, 1988)

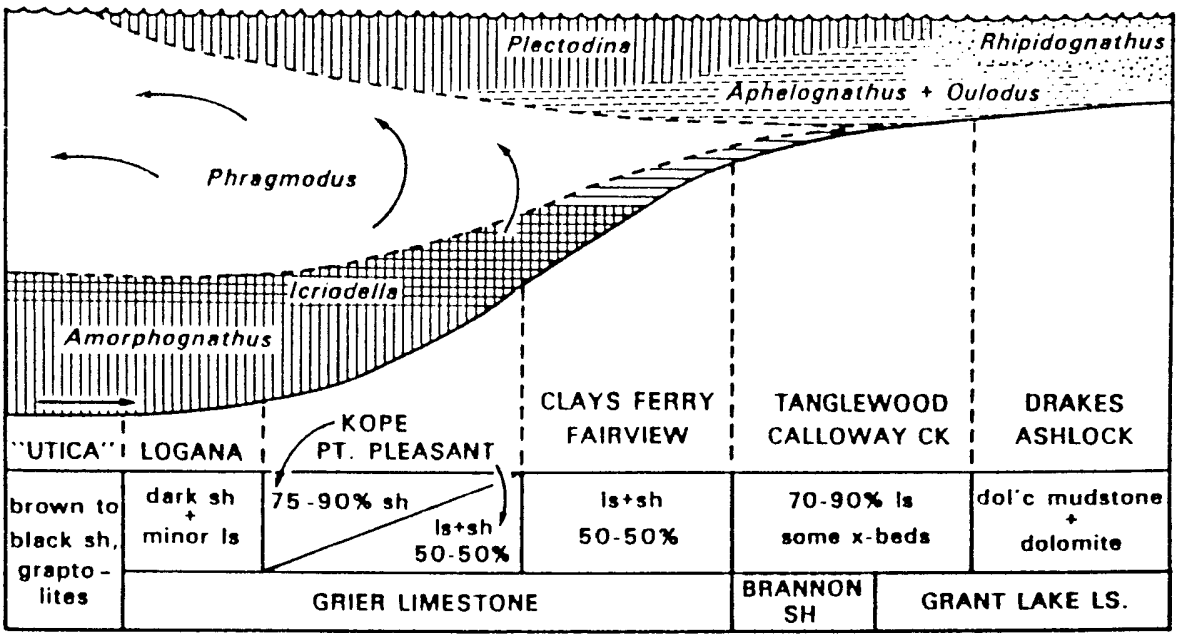


Fig. 7.3. Hypothetical transect of the Cincinnati Region, reconstructed from interpretations of depositional environments of Middle and Upper Ordovician rocks. Above are interpreted distributions of characteristic conodonts, inferred from the relative abundance and lateral distribution of their remains in the facies named below.

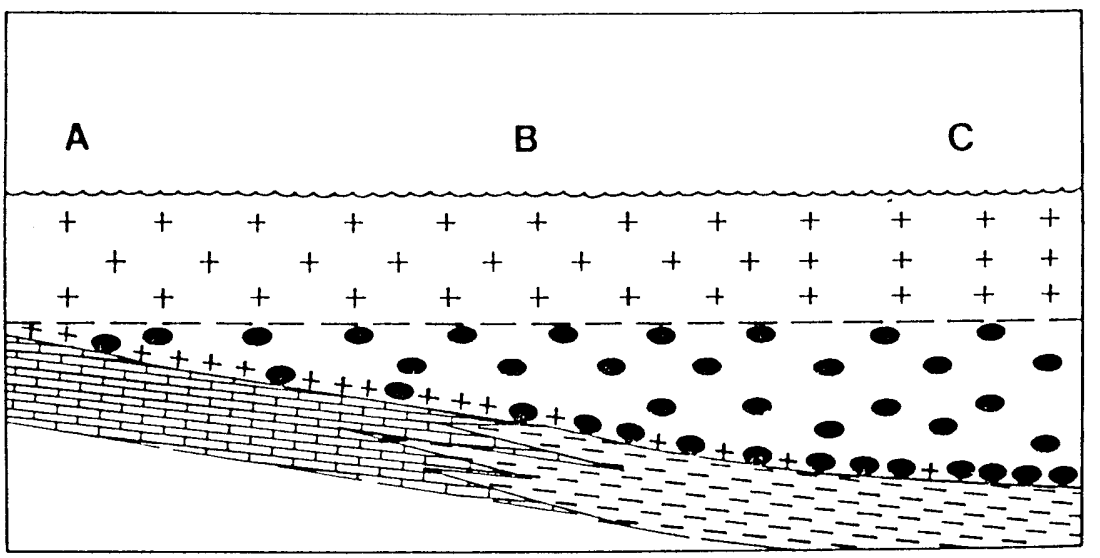


Fig. 7.1. Schematic explanation of the depth-stratification model of Seddon and Sweet (1971). Diagram shows two species; one indicated by crosses is uniformly distributed in a surficial water stratum; the other, indicated by filled ellipses, is uniformly distributed in a deeper-water stratum. Elements of both species would accumulate together on the seafloor, but between A and B those of the "cross" species would dominate, whereas between B and C the reverse would be true. Redrawn, with omissions, from Seddon and Sweet (1971).

Figure 10 Paleogeography of eastern North America in Middle and Late Ordovician time. (From Sweet, 1988)

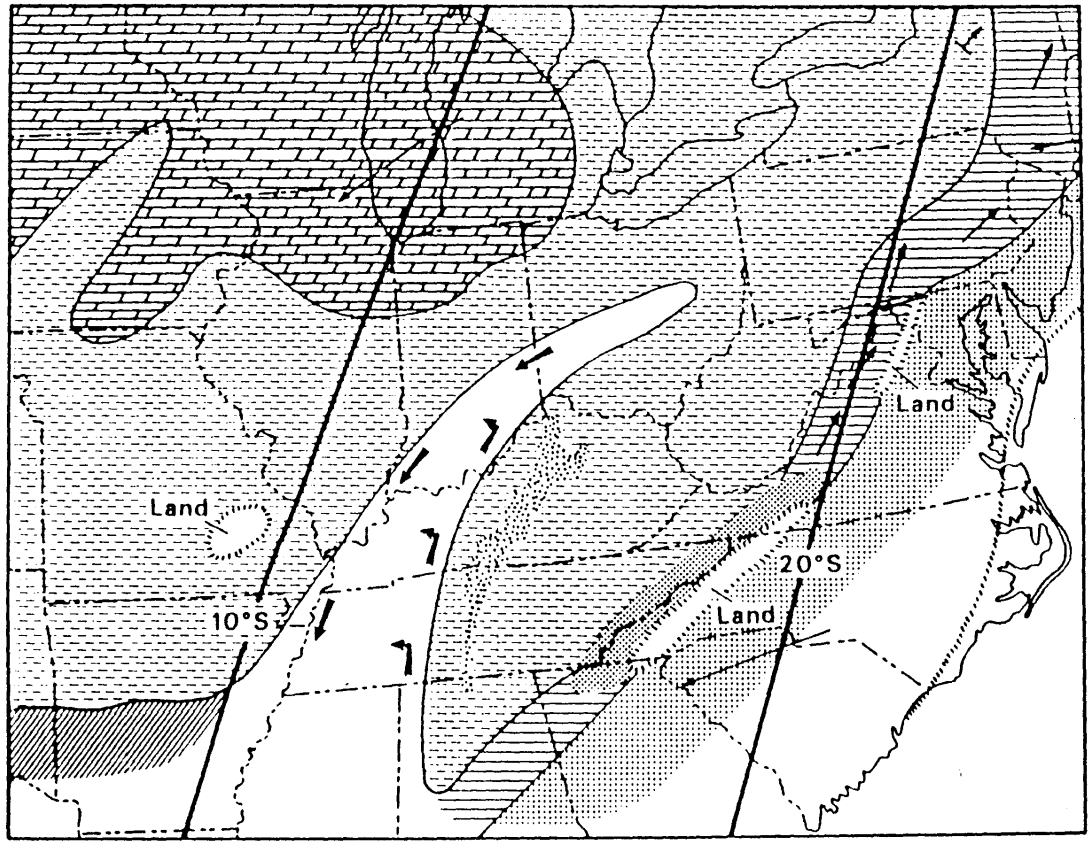
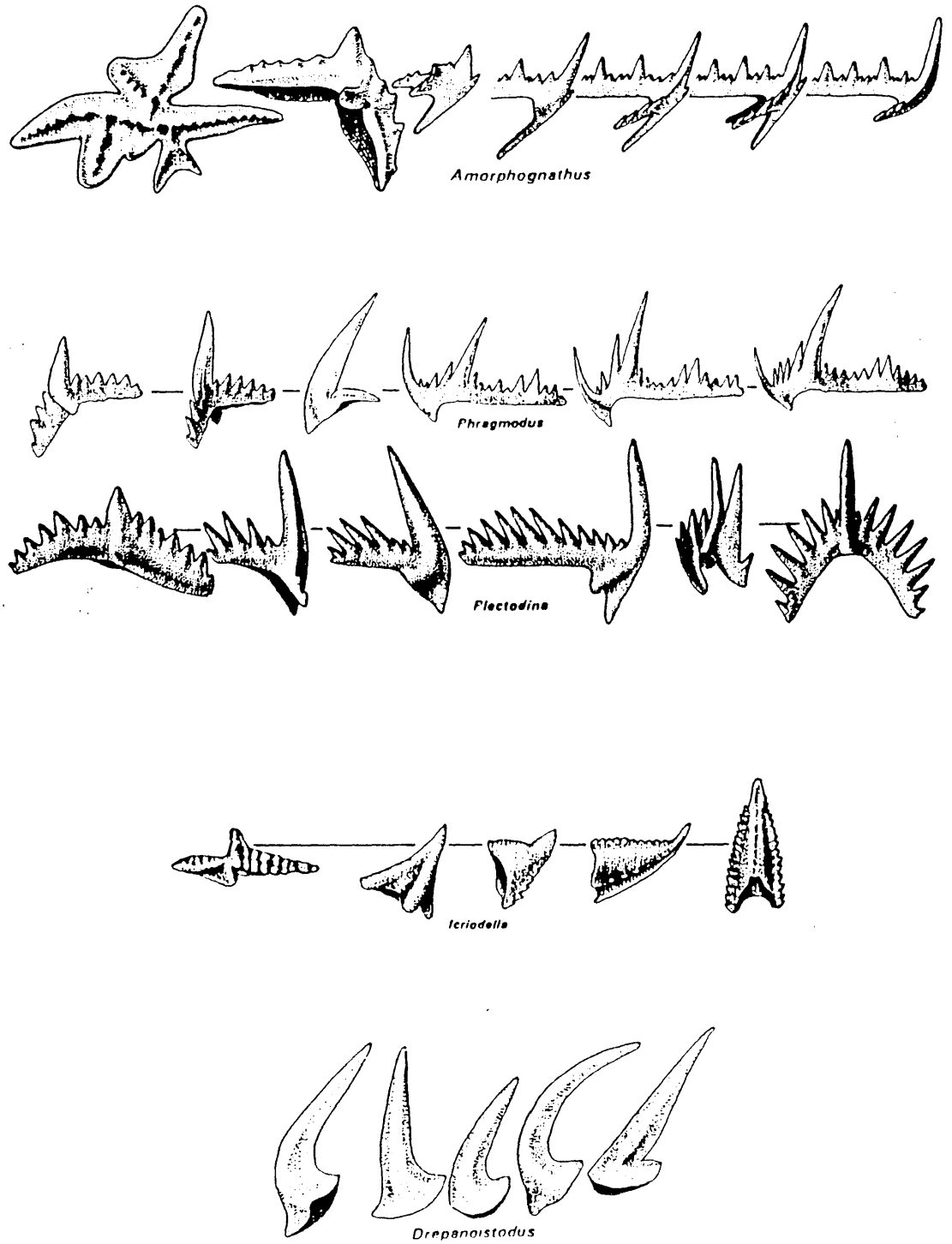


Fig. 7.2. Situation of the Cincinnati Region in the Middle and Late Ordovician. The Cincinnati Region is the tri-state tract in the center of the map. In general, it was part of a broad carbonate shelf to which terrigenous material was introduced from the southeast and that was bordered on the northwest by the distal extremity of a narrow, deep sag (white) that permitted connection with cold, phosphate-rich waters to the south. Approximate positions of 10° and 20° S paleolatitudes indicated by heavy lines; light arrows suggest prevailing-wind direction; heavier arrows in sag suggest wind-driven circulation pattern permitting upwelling of phosphate-rich water in Cincinnati Region. Adapted from Cressman (1973).

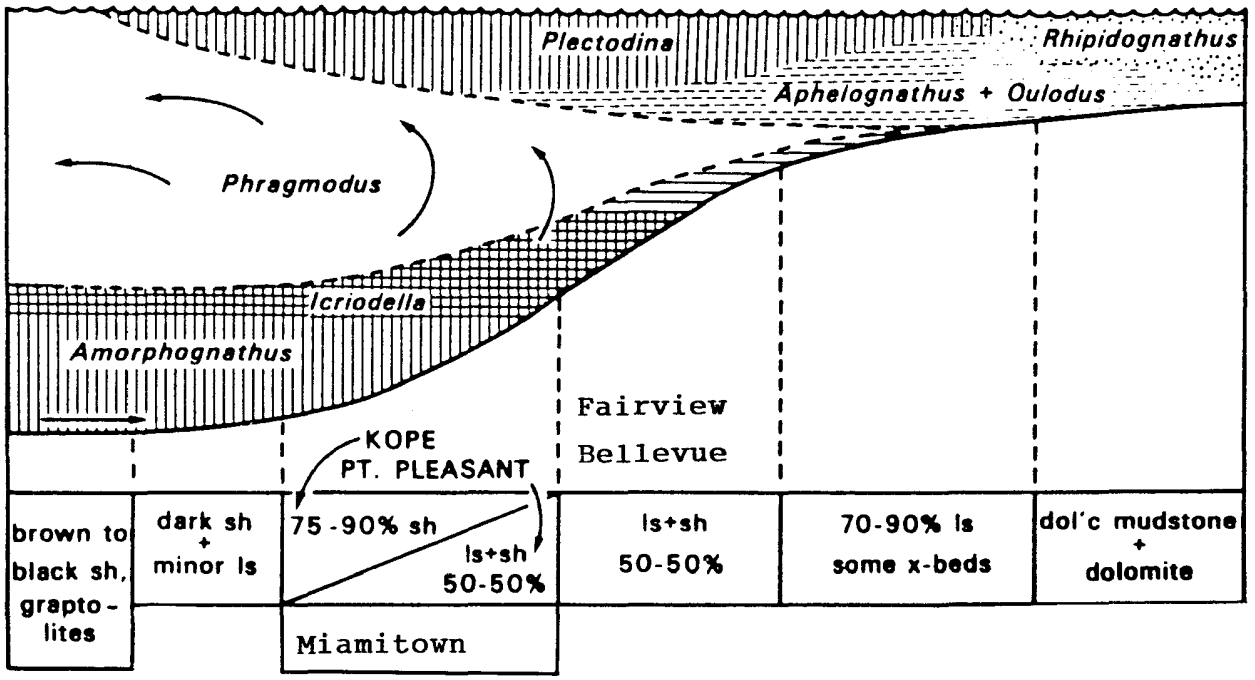
Figure 11 Elements of the apparatuses of conodont genera found in the Miamitown Shale. Figures from Sweet (1988)



The key conodont for indicating deep water conditions is Amorphognathus, as shown by its position in Sweet's transect (see Figures 10). The bottom of the Miamitown West section, sample 89MI1-8 in the Fairview Formation, contains no Amorphognathus elements. The next sample up, sample 89MI1-7, is within the Miamitown Shale and contains 3% Amorphognathus elements. The next sample up, sample 89MI1-6, contains 13% Amorphognathus elements which is the highest percentage of elements per sample. The relative amount of elements per one kilogram of sample also increases from sample 89MI1-7 to 89MI1-6. In samples 89MI1-5 to 89MI1-3 there is a reduction in the percentage of Amorphognathus from 4% in sample 89MI1-5 to 1% in sample 89MI1-3. The percentage of Amorphognathus in samples 89MI1-3 to 89MI1-1 increases from 1% in sample 89MI1-3 to 6% in sample 89MI1-1. Sample 89MI1-2 and 89MI1-1 are both in the Bellevue Formation. There is an increase in the percent of Amorphognathus as you move from the Fairview Formation and up into the Miamitown Shale. This is followed by a decrease in the percentage of Amorphognathus at the top of the Miamitown and slight increase in the overlying Bellevue Formation (see Table 4 and 6).

The Miamitown East section shows a drop in the percentage of Amorphognathus from the base of the Miamitown Shale to the top (see Table 4). From sample 89MI2-3 to sample 89MI2-1 there is a drop from 9% to 1%. The relative abundance of Amorphognathus also decreases from sample 89MI2-3 to 89MI2-1. This could indicate a sequence from relatively deep to shallow water conditions.

Figure 12 Interpretation of the depositional environment of the Miamitown Shale in terms of Sweet's (1988) biofacies model. (Modified after Sweet, 1988)



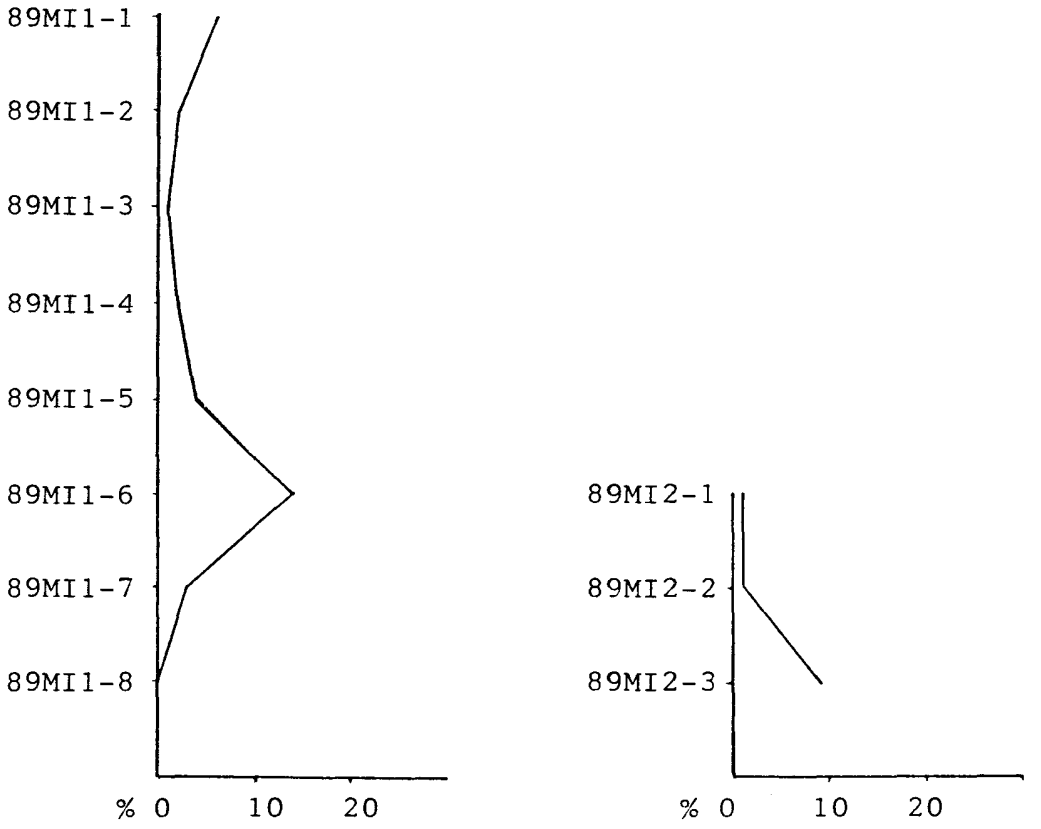
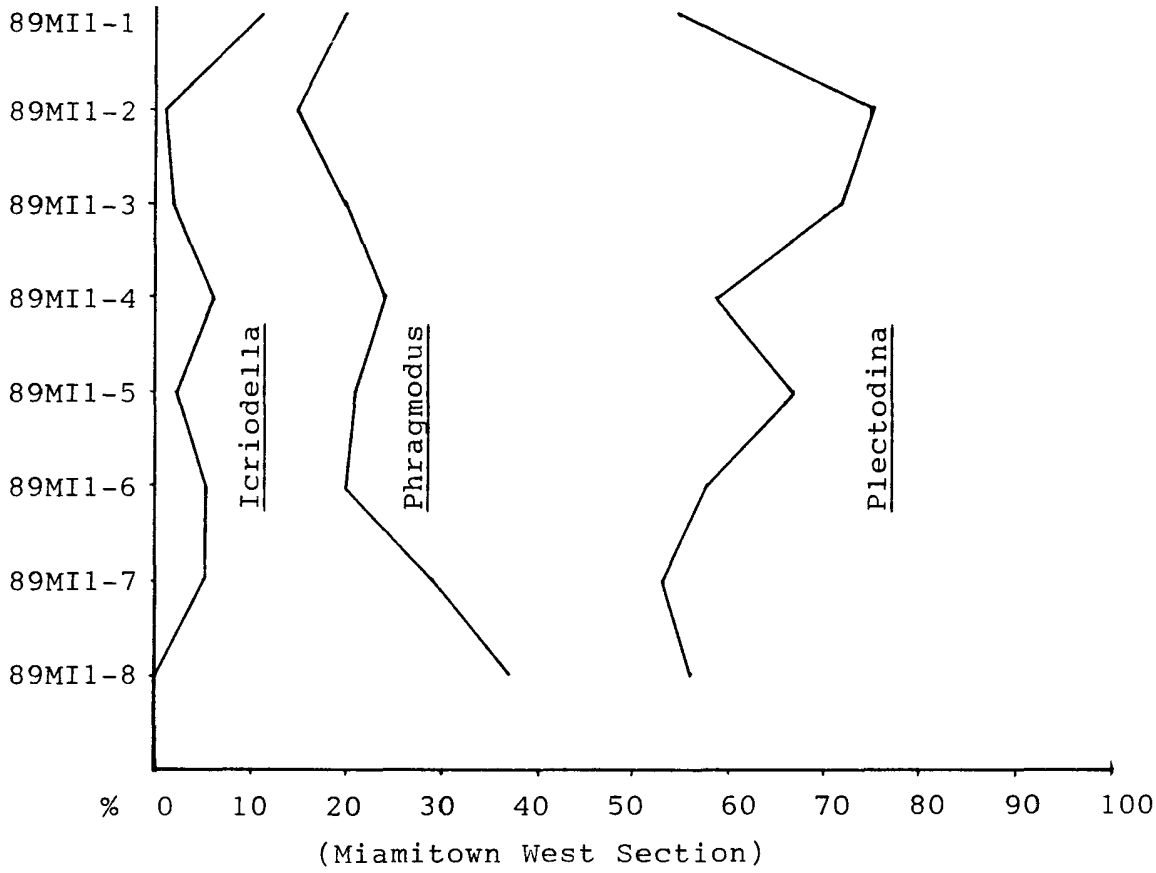


Table 4 Percentage of Amorphognathus elements in the conodont samples of the Miamitown West Section (Left column) and the Miamitown East Section (Right column).



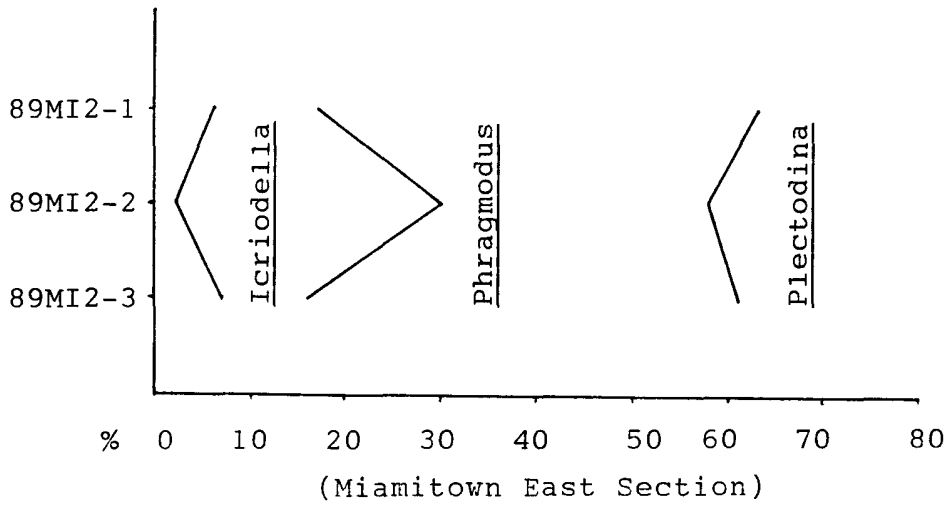


Table 5 Percentage of Plectodina, Phragmodus, and Icriodella.

Another good indicatior of relatively deep water conditions is Icriodella. According to the transect produced by Sweet (1988), Icriodella lived just above the bottom in relatively deep water (see Figures 12).

The Miamitown West section contains Icriodella in all sample horizons except sample 89MI1-8, which is from the Fairview Formation. The samples above the top of the Fairview Formation show an increase in the relative abundance of Icriodella, from sample 89MI1-7 to sample 89MI1-4. The percentage of Icriodella in the samples also increases at sample 89MI1-4. The relative abundance of Icriodella then decreases from sample 89MI1-4 to 89MI1-3 along with the species percentage. In the Miamitown West section both the relative abundance and percentage of Icriodella increase from the base to the approximate center of the Miamitown Shale and then decrease from the center to the top of the unit (see Table 5 and 6).

The Miamitown East section shows an increase in the relative abundance of Icriodella from the base of the Miamitown Shale to the top. The percentage of Icriodella at this location remains relatively constant (see Table 5).

The percentage and relative abundance of Phragmodus can also be used to determine relative water depth. The Miamitown West section shows a general increase in the relative abundance of Phragmodus from the base of the Miamitown Shale upwards from sample 89MI1-8 to 89MI1-4 (see Figure 6). The percentage of Phragmodus decreases from sample 89MI1-8 to sample 89MI1-6, then increases slightly to sample 89MI1-4 and then decreases from

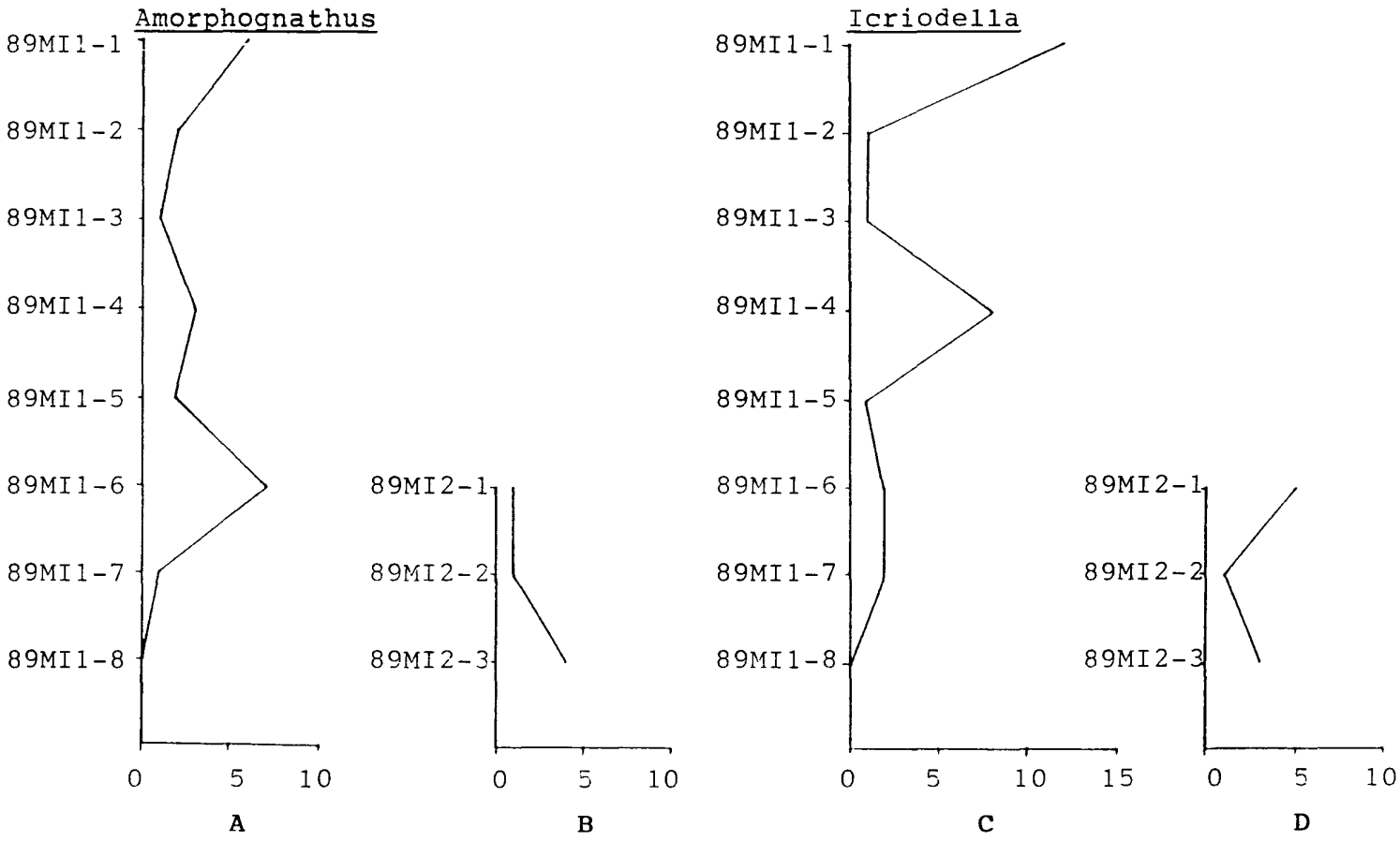


Table 6 Relative abundance chart of the number of conodont elements per kilogram of sample. **A**, Miamitown West; **B**, Miamitown East; **C**, Miamitown West; **D**, Miamitown East. Designations along vertical axis are sample numbers, figures along the horizontal axis are number of elements per kilogram.

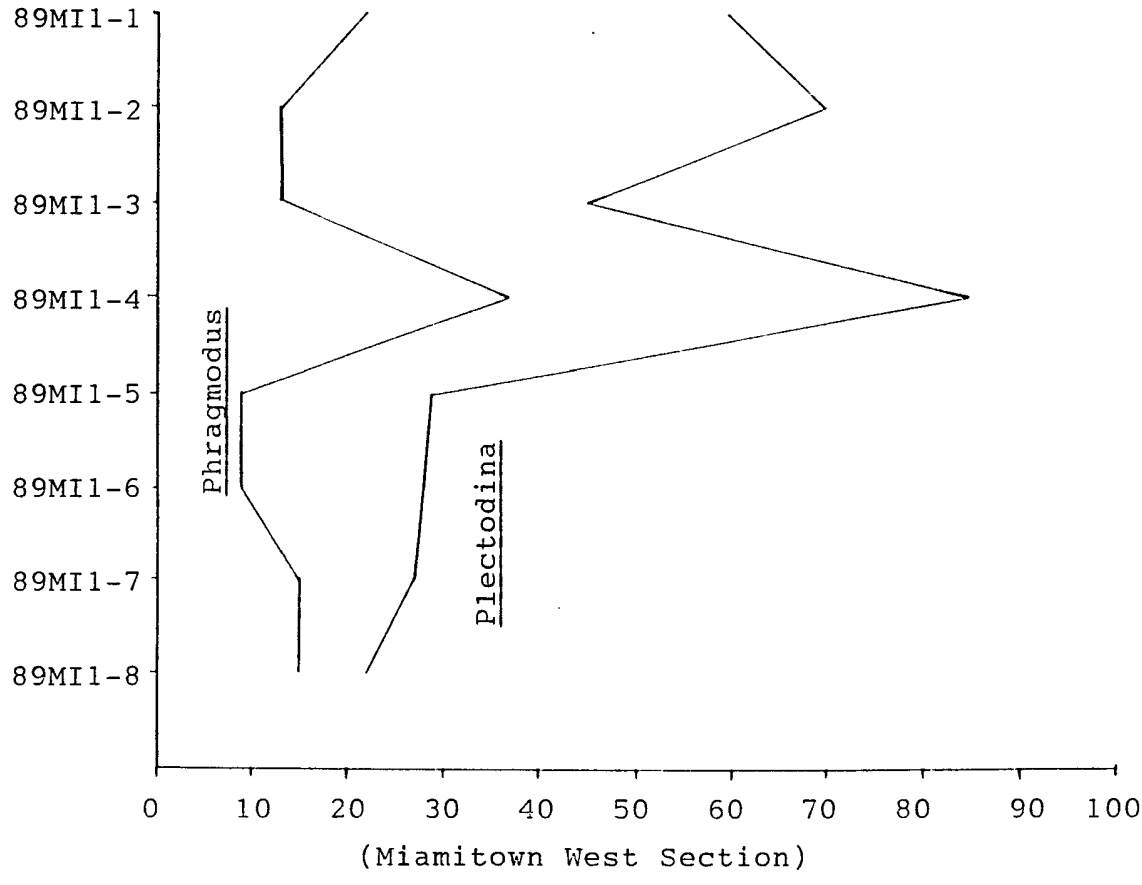
sample 89MI1-4 to 89MI1-2 (see Table 5). The relative abundance of Phragmodus shows a substantial increase from sample 89MI1-8 to 89MI1-4 and decrease from sample 89MI1-4 to 89MI1-1.

The Miamitown East section shows an increase of Phragmodus within the Miamitown Shale from sample 89MI2-3 to 89MI2-2. This number decreases from sample 89MI2-2 to 89MI2-1. The relative abundance of Phragmodus shows a gradual increase from sample 89MI2-3 to 89MI2-1 (see Table 5 and 6).

Another genus that is useful in determining relative water depth is Plectodina. The Miamitown West section contains a relative abundance of Plectodina that increases from the base of the section at the level of 89MI1-8 to the top of the section at the level of 89MI1-1 (see Table 6). The relative abundance of Plectodina is highest in sample 89MI1-4 which is located within the Miamitown Shale (see Figure 6). The percentage of Plectodina in the Miamitown West section show a steady increase from sample 89MI1-8 to sample 89MI1-5, then there is a sudden decrease at sample 89MI1-4, followed by an increase in sample 89MI1-2.

The Miamitown East section contains a relative abundance of Plectodina that increases steadily from 89MI2-3 to 89MI2-1 (see Table 6). The percentage of Plectodina decreases slightly from sample 89MI2-3 to 89MI2-2 and increases from 89MI2-2 to 89MI2-1 (see Table 5).

By observing the percentage of each genus that makes up a particular sample we can get an idea of the relative water depth. The absence of Amorphognathus and Icriodella at the top of the Fairview Formation in the Miamitown West section, indicates a



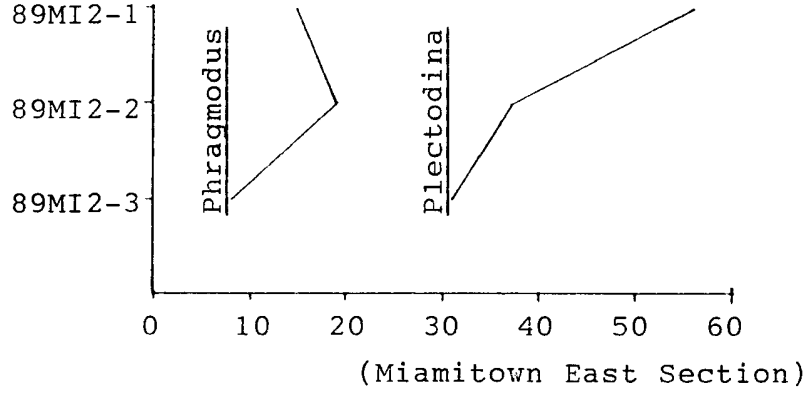


Table 7 Relative abundance of Plectodina and Phragmodus from the Miamitown West and East Sections. Vertical figures are the sample numbers horizontal figures are the number of elements per kilogram.

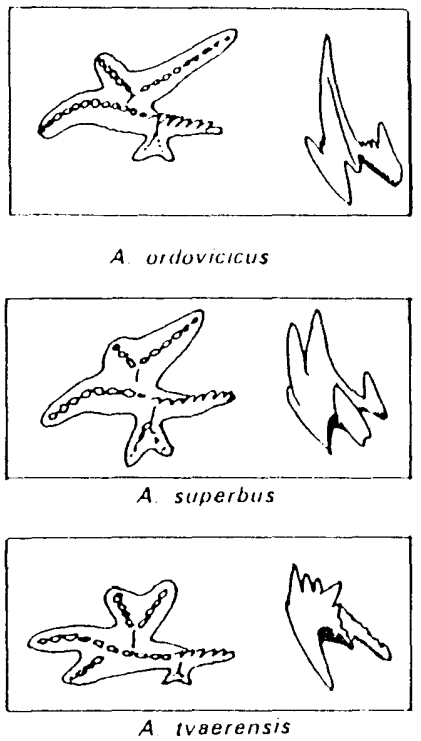
relatively shallow water environment. The relatively deep water Amorphognathus is most prevalent in the middle of the Miamitown West section, indicating a deeper water environment at this horizon. The lower percentage of Plectodina to Phragmodus in samples 89MI1-7, 89MI1-6, and 89MI1-4 also shows that the relative water depth was greater during the deposition of the Miamitown Shale (see Figure 12). The Miamitown-Bellevue contact is in an interval of interbedded limestone and shale layers that show that the deeper water or transgressive event was beginning to be replaced by a shallower depositional environment. The top of the Miamitown Shale is defined (in this report) as the lowermost major limestone layer seen in the Bellevue Formation (see Figures 6 and 7).

The Miamitown East section also shows that the depositional environment of the Miamitown Shale occurred in deeper water. The percentage of Plectodina to Phragmodus in sample 89MI2-2 indicates a deeper water environment than the sample 89MI2-1 from the Fairview Formation, and sample 89MI2-3 from the Bellevue Formation (see Table 5). The presence of Amorphognathus and Icriodella at the base of the Miamitown Shale in the Miamitown East section shows that the relative deep water conditions began at the top of the Fairview Formation in this section.

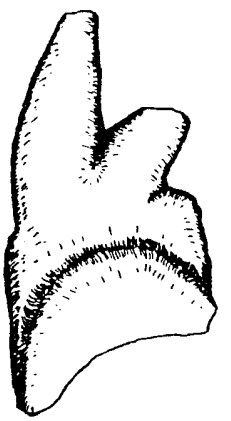
Biostratigraphy

The Miamitown Shale is placed in the Cincinnatian Series, and more specifically, the Maysvillian Stage. The position of the Amorphognathus ordovicicus-Amorphognathus superbus zonal boundary within this part of the Maysville Stage has been

Figure 13 Index conodonts that define the Amorphognathus zones. **A**, key elements of A. tvaerensis, A. superbus, and A. ordovicicus (From Bergström, 1982); **B**, M element of A. superbus from sample 88B60-1, lower Miamitown Shale.



A



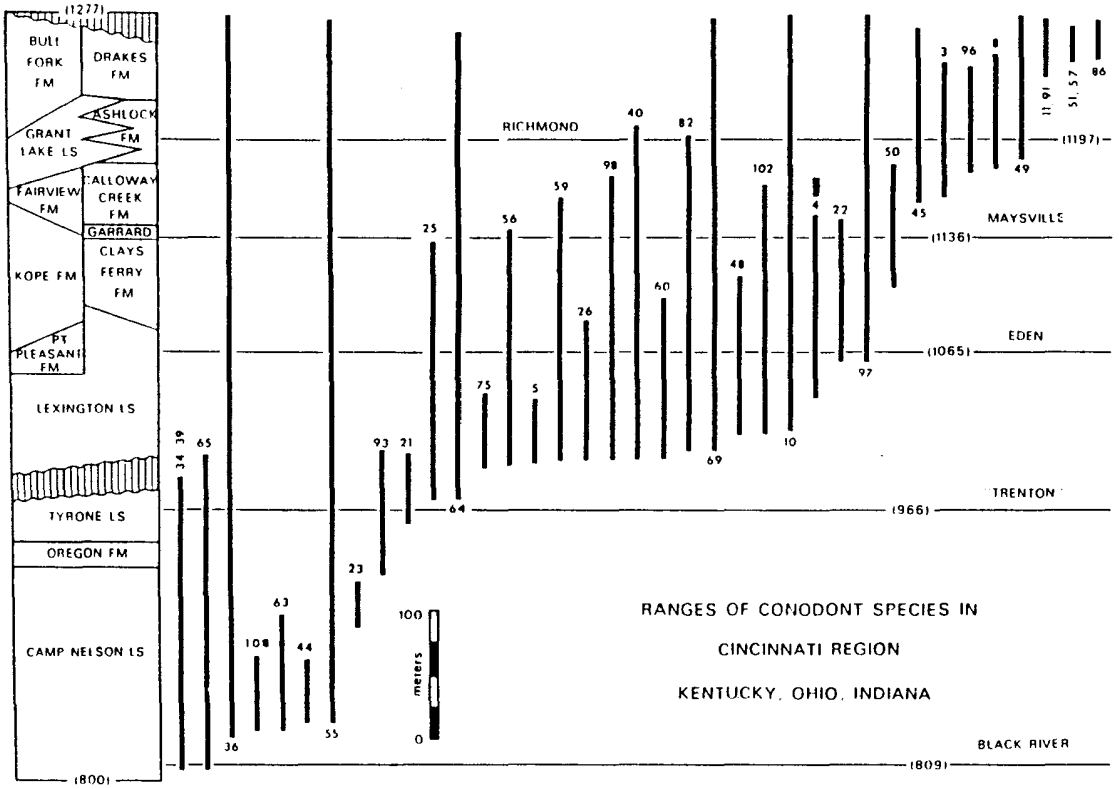
B

X225

uncertain with regards to its postion within the Miamitown Shale. The Amorphognathus ordovicicus-Amorphognathus superbus boundary is defined as the horizon where Amorphognathus superbus (see Figure 14) evolves into Amorphognathus ordovicicus (Bergstrom, 1982). Amorphognathus ordovicicus has not been found in the Cincinnati region of Ohio so the level of the Amorphognathus superbus-Amorphognathus ordovicicus boundary is still uncertain. The age of the Amorphognathus superbus zone is Late Middle Ordovician and early Late Ordovician (Bergstrom and Sweet, 1971).

Amorphognathus superbus was found in the Miamitown West section approximately 3 meters from the top of the Fairview Formation in sample 89MI1-6, or sample 88B60-1 (see Figure 6). The key element that defines Amorphognathus superbus is the holodontiform element (see Figure 13). This key element was found only after picking 6 kilograms of sample, so the relative abundance of this element is extremely low. The 6 kilogram sample, that corresponds to sample 89MI1-6 in the Miamitown West section, was collected by Dr. S.M. Bergstrom and used with his permission in this report. The presense of Amorphognathus superbus within the Miamitown Shale shows that the Amorphognathus superbus zone extends upward into the unit. Figure 14 shows an earlier interpretation of the level of the Amorphognathus ordovicicus-Amorphognathus superbus boundary. This level is not above the Farirview Formation. Since the Miamitown Shale is above the Fairview Formation and Amorphognathus superbus was found within the Miamitown Shale, the Amorphognathus ordovicicus-Amorphognathus superbus boundary should be moved up slightly to

Figure 14 A, ranges of Middle and Upper Ordovician conodonts in the Cincinnati Region, from Sweet (1984) with revision of range of A. superbus (species 4). B, key list of species shown in A, from Sweet (1984).



A

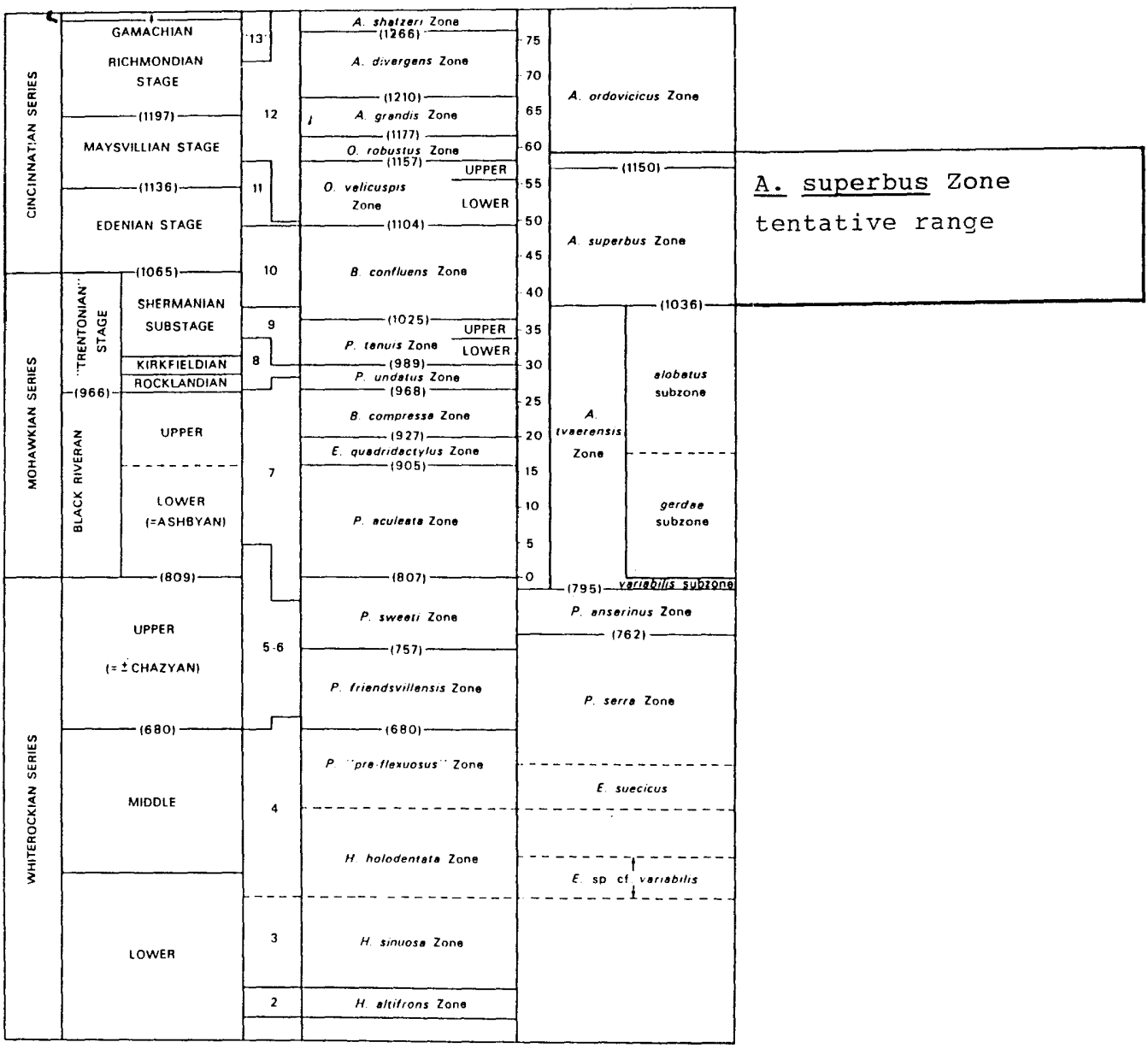
Appendix

The Composite Standard Section

Species No.	*Species Name*	*Range in CSS*
3	*Amorphognathus ordovicicus*	1150–1269
* 4	*A. superbus*	1036–1151
5	*A. tvaerensis*	968–1035
6	*Aphelognathus divergens*	1210–1264
7	*A. floweri*	1153–1255
8	*A. grandis*	1177–1248
11	*A. pyramidalis*	1234–1270
12	*A. shatzeri*	1266–1288
15	*Appalachignathus delicatulus*	778– 907
16	*Belodella nevadensis*	603– 949
21	*Belodina compressa*	927–1019
22	*B. confluens*	1025–1169
23	*B. monitorensis*	698– 953
25	*Bryantodina abrupta*	973–1133
26	*B. staufferi*	997–1085
27A	*B.* n. sp. cf. *B. typicalis*	795– 824
27B	*B. typicalis*	967–1000
28	*Chirognathus duodactylus*	967– 987

B

Figure 15 Known range of the A. superbus Zone in the Cincinnati Region. Zonal nomenclature from Sweet (1984).



take this into account. Figure 14 has been modified to show the extent of the boundary before this report, below the number 4 in Figure 14, and after the findings of this report, the line above the number 4 in Figure 14. Figure 15 has been modified to show the revised Amorphognathus ordovicicus-Amorphognathus superbus boundary. This boundary can only be approximated due to the lack of the key holodontiform element in the higher samples. Identification of Amorphognathus ordovicicus or Amorphognathus superbus in the upper part of the Miamitown Shale at both localities has been uncertain due to the lack of this key element. However, it has been established that the Amorphognathus ordovicicus-Amorphognathus superbus boundary is above the Fairview Formation and is located in either the upper portion of the Miamitown Shale or above the Miamitown Shale.

Conclusion

The depth-stratification model proposed by Sweet (1988) shows that the conodont elements found in the Miamitown Shale were deposited under relatively deep water conditions. The relative water depth increases from the Fairview Formation and up into the Miamitown Shale and decreases from the Miamitown Shale up into the Bellevue Formation. This shows that a transgressive event occurred during the deposition of the Miamitown Shale.

The Miamitown Shale was originally thought to represent the lower half of the Maysville Stage. The presence of A. superbus in this unit moves the level of the A. ordovicicus-A. superbus zonal boundary up into the top part of the Miamitown Shale or

above (see Figure 14 and 15). The exact location of the A. ordovicicus-A. superbus is still uncertain but in this study it has been shown that the zonal boundary is above or within the Miamitown Shale.

Acknowledgments

I would like to thank Dr. S.M. Bergstrom for his advice in the field, laboratory, and office. I would also like to thank Dr. M. Kleffner for his help in creating the photographs used in Plate I. In addition, I would like to thank my parents, Dennis A. and Grace M. Izold, and my brother Andrew A. Izold for their support throughout this project.

Plate

Plate Explanation

(Conodonts from the Miamitown Sections investigated)

1. Amorphognathus superbus, Pa element, upper view, sample 89MI1-6, **X80.**
2. Amorphognathus sp., Sd element, right lateral view, sample 89MI1-3, **X125.**
3. Amorphognathus superbus, Pb element, upper view, sample 89MI1-6, **X80.**
4. Icriodella superba, Pa element, right lateral view, sample 89MI1-3, **X60.**
5. Icriodella superba, Sb element, upper view, sample 89MI1-1, **X70.**
6. Plectodina furcata, Sb element, lateral view, sample 89MI2-2, **x40.**
7. Plectodina furcata, Sa element, posterior view, sample 89MI1-4, **X70.**
8. Plectodina furcata, Sc element, right lateral view, sample 89MI1-3, **X40.**
9. Plectodina furcata, Pb element, lateral view, sample 89MI1-3, **X80.**
10. Plectodina furcata, M element, lateral view, sample 89MI1-2, **X45.**
11. Plectodina furcata, Pa element, lateral view, sample 89MI1-3, **X70.**
12. Phragmodus undatus, Sa element, lateral view, sample 89MI1-3, **X60.**
13. Phragmodus undatus, Pa element, lateral view, sample 89MI1-1, **X50.**
14. Phragmodus undatus, M element, lateral view, sample 89MI1-2, **X60.**
15. Drepanoistodus suberectus, straight coniform element, lateral view, sample 89MI1-4, **X70.**
16. Drepanoistodus suberectus, curved coniform element, lateral view, sample 89MI1-2, **X60.**
17. Drepanoistodus suberectus, oistodontiform element, lateral view, sample 89MI1-3, **X110.**

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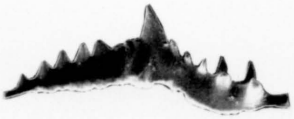

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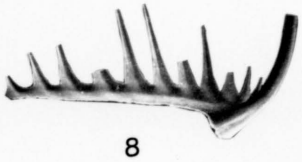

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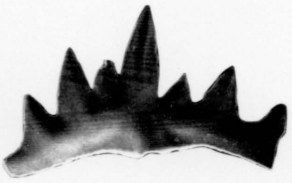

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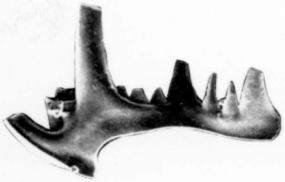

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Plate I

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